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# **FARMING OF MUSSELS AND OYSTERS**

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## **ABSTRACT**

This paper reviews the works on mussel and oyster culture conducted from 1975 to 1985 by the Southeast Asian Fisheries Development Center Aquaculture Department at Tigbauan, Iloilo, Philippines. Innovative techniques developed in increasing collection of natural seeds and in improving farming techniques are presented. Results of the work on artificial seed production, bacterial depuration, uptake and elimination of heavy metals by green mussel, investigations on red tides, and microbiology of spoilage are discussed.

## **INTRODUCTION**

In Asia and the Pacific, bivalves represent a high quality food resource, either harvested from the wild or cultivated in farms. Compared to crustacean culture, annual production of bivalves per ha is higher at  $1.5 \times 10^4$  kg oysters,  $1.0 \times 10^4$  kg to  $2.5 \times 10^4$  clams (depending on market size), and  $3.0 \times 10^4$  to  $5.0 \times 10^4$  kg mussels (Utting 1987).

Interest in bivalve culture in Southeast Asia has grown considerably. The most important species are oysters, mussels, clams, cockles, and scallops. Mollusc production, however, has declined significantly in recent years primarily due to the decreasing production in Malaysia and Thailand arising from the rapid depletion of natural breeding stocks of cockle and mussel (Table 1). Nevertheless, molluscs accounted for approximately 35% of the total production of coastal aquaculture in 1984 in terms of gross weight (Shang 1986).

Table 1. Production of molluscs from coastal aquaculture by country, 1975-84 (Csavas 1985)

Country	1975	Unit: 1000 MT		1983	1984	Average annual growth rate	
		1981	1982			1975-84	1981-85
PR China	248.9	301.6	343.4	309.1	372.6	% 5.0	% 5.9
India	0.1	1.8	1.8	4.0	4.0	390.0	30.5
Indonesia	—	—	—	—	—	—	—
Japan	278.0	302.0	335.2	347.1	347.1	2.3	3.3
Malaysia	53.5	121.3	121.3	49.4	49.4	0.1	-5.9
Philippines	—	12.8	25.3	29.8	34.9	—	43.0
Taiwan PC	30.9	44.7	46.2	53.7	59.2	9.2	8.1
Thailand	23.0	53.7	23.9	29.8	29.8	3.0	-11.0
Total	634.4	837.9	897.1	822.9	891.6	4.1	1.6

SEAFDEC AQD started its work on bivalve molluscs in 1975 when a Mussel Research Project was set up with the assistance of the New Zealand Government. The project first undertook a survey of the mussel farming industry. Later, it conducted a baseline study on the biology of local mussels and preliminary experiments on mussel farming (Tortell et al 1978, Yap 1978, Yap et al 1979).

## SEED COLLECTION

SEAFDEC AQD started a spatfall-forecasting program in Hima-maylan River in Negros Occidental in 1979 for oysters and another in 1981 in Batan Bay, Aklan for mussels. The main activities of the forecasting program were: (1) monitoring of daily counts of oyster or mussel larvae in the plankton and (2) monitoring of actual setting of larvae on standardized collectors installed in oyster-mussel farm sites.

For oysters, series of collectors were set out in the sampling area: one upriver, another located seaward, and a third in-between. The sample collectors are retrieved and examined every week at a designated day. In addition, plankton tows were carried out daily during flood tide at a standard distance of 360 m. For mussels, a set of 5 sample collectors, each consisting of 30 cm lengths of rope collectors strung across a frame hung from a floating raft, was installed. At weekly intervals, 5 new sample collectors were exposed while 5 old ones were retrieved. This provided good indications for cumulative settlement of mussel spat. For analysis, samples were passed through a series of sieves which grade the spat according to size and age.

The preliminary reports (Young et al 1981) are not adequate as yet for formulating a spatfall forecasting scheme, but a few general observations are significant:

1. When the count of mature larvae exceeds 5 oyster larvae/100 sample and persists for at least 3 days, spatfall maybe expected very soon. This spatfall period may last up to 1 month so that the best strategy for collecting oyster spat is to spread out the collection effort over the spatfall period instead of putting out all spat collectors at the same time.
2. For commercial farming operations, a good or substantial set of oyster seed should yield at least 15 spat/shell in a surface area of 40m<sup>2</sup>. For mussel seed, a count of 200-500 spat/m of

rope or 70-85 spat/30 cm of sample rope collector indicates a good settlement for commercial production.

## FARMING TECHNIQUES

Countries which have successfully cultured bivalve molluscs have developed their own system of culture which depends entirely on natural seed stock. Seeds for farming are either gathered from natural seed beds or collected by using suitable materials for collecting seed from natural grounds.

A number of natural and synthetic ropes have been used for spat collection. Natural rope fibers have been found to be attractive to mussel larvae, but they do not last long. On the other hand, synthetic ropes like polyethylene or polypropylene ropes will stand up to several years, but they catch less spat unless a heavy spatfall occurs. The catching qualities of synthetic ropes, however, can be improved by inter-weaving more suitable cultch among the strands of the rope by wrapping fibrous materials externally around or by tying short pieces of fibrous materials into the rope. Coir, a natural coconut fiber, can be interwoven among the synthetic braid during the making of the rope or may be wrapped around it. Coir biodegrades rapidly in sea water but the mussel larvae because of its ability to move will have attached themselves securely before the coir is destroyed. Another is to intermittently insert into the ropes short segments of sacking material or husks segments cut from a mature dried coconut (Yap et al 1979, Sitoy et al 1983). Other materials that can be used are old frayed ropes, polyethylene strands used in making rice sacks, plaited ropes of vegetable fibers, and other fibrous materials (Young 1984).

Farming methods for oyster and mussel in the Philippines make extensive use of bamboo stakes which increase siltation rate in areas occupied by such stake-farms. The bamboo poles serve as cultch for the settling of mussel larvae, and no thinning or transplanting is done during the grow-out. An alternative method is the floating raft culture shown in Fig. 1 (Anon. 1979, Sitoy et al 1983, Sitoy 1984).

Mussel farming using rafts has several advantages: mussel grow faster; regular thinning can be done; rafts can be moved around to prevent siltation. It can easily be constructed out of durable materials

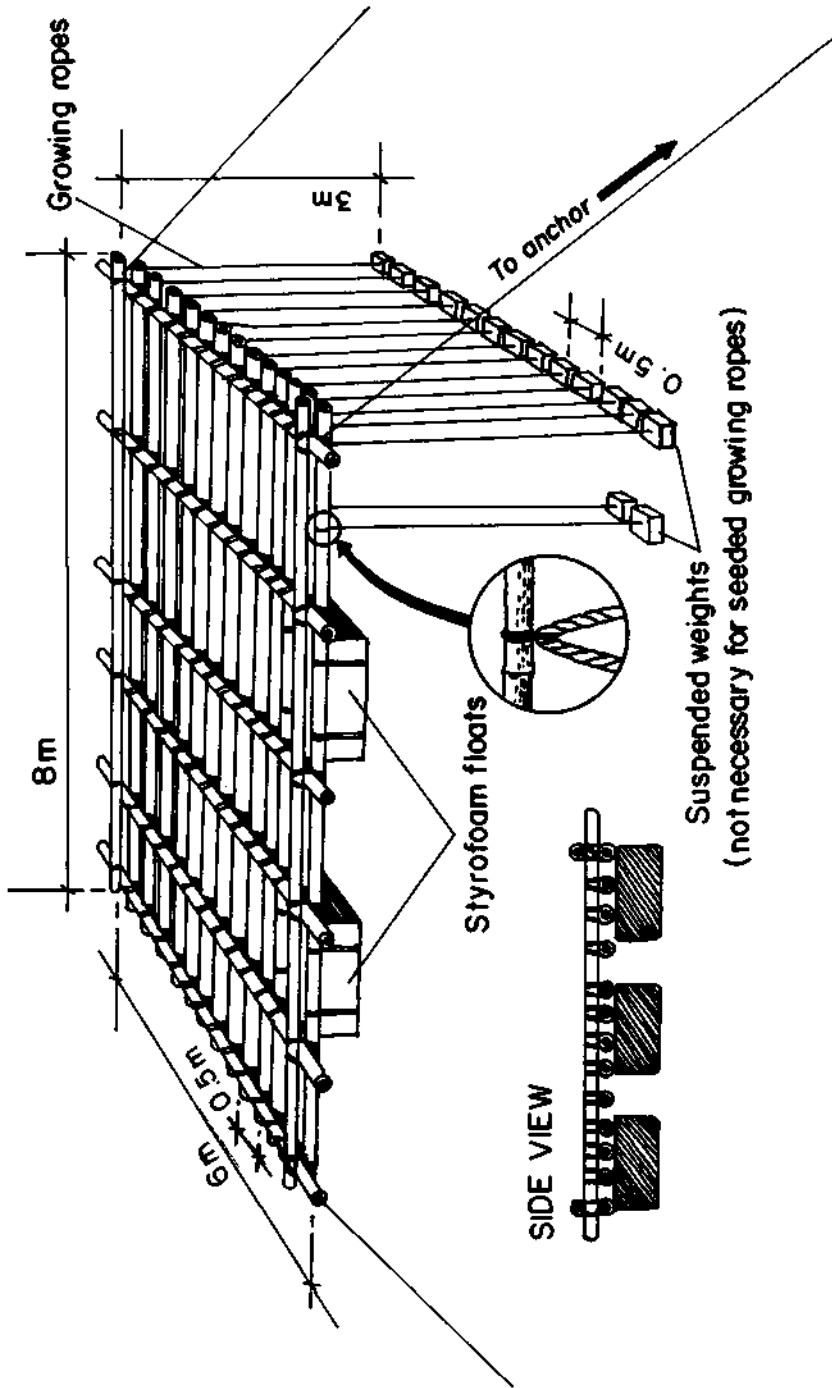


Fig. 1. Diagram of a mussel raft unit (Sitoy et al 1983)

lasting for several years. Aside from providing higher production per unit area the technique offers a convenient method of transplanting seeds to other areas without natural stocks (Aypa 1980; Walter 1981, 1982; Tabbu et al 1983).

## SEED PRODUCTION

Seed production of bivalves at AQD started in 1979. Young (1979) successfully spawned the green mussel (*P. viridis*) in the laboratory. The slipper oyster (*C. iredalei*) and the windowpane shell (*Placuna placenta*) were also successfully reared through its larval stages to metamorphoses and settlement. A detailed description of the larval development and morphology of *C. iredalei* is presented in Table 2 and that of *P. placenta* in Table 3. Recently, the Asian moon scallop (*Amusium pleuronectes*) was successfully spawned and the eggs reared through metamorphoses (Young unpublished). Newly developed D-veliger larvae measure 107  $\mu\text{m}$  in length 83  $\mu\text{m}$  high, reaching the umbo veliger stage at 145  $\mu\text{m}$ . Unlike *Placuna*, Asian moon scallop shell is equivalve and broad. Pediveligers average 107  $\mu\text{m}$  in length and show alternate swimming and crawling movements. After day 13 from spawning, prediveligers attach bysally to objects and remain there until they reach an average diameter of 5 mm. As early as 1 mm in size, *Amusium* juveniles already show characteristic jet-propulsion movements in pectinids.

Young (unpublished) successfully reared oyster larvae at a density of 3-5 ind/ml and fed with a combination of *Isochrysis galbana* and *Chaetoceros calcitrans* at  $3.0\text{-}5.0 \times 10^4$  cells/ml. The larvae were successfully induced to set on crushed windowpane shells spread on the bottom of a floating screened PVC-frame after 17 days of rearing from hatching. A week from setting, about  $5.0\text{-}6.0 \times 10^3$  young oyster spat were retrieved and transferred to an upwelling-type nursery system where they were fed *ad libitum*. But growth in the nursery was limited by insufficient food and less than 3% survived. After a month the remaining spat reach 3-11 cm. A batch of mussel larvae was also reared to metamorphosis. After 19 days, ready-to-settle larvae attached themselves to strips of knotless nylon netting suspended in the tank.

An experiment to assess the suitability of Tahiti's low-density technique (AQUACOP 1979, 1980, 1984) against China's high-density method (Fusui et al 1981) was conducted. Four 750 l cylindrical tanks were stocked with mussel larvae at 5/ml and two U-shaped

Table 2. Main features of the larval development of *Crassostrea iredalei* (Temperature, 26.5-30°C; salinity, 30-32 ppt)  
Ver 1986)

Stage	Age	Mean Size (µm)	Range (Mm)	SE (Mm)	n	Remarks
Straight-hinge veliger	22 hr-4 days	L = 74	64-84	0.528	110	D-shaped; shell asym-
		H = 67	56-80	0.708	110	metrical but equivalved
		D = 48	41-61	0.948	41	
Umbonate veliger	5-22 days	Hinge-line length = 50				
			L = 85-275		419	rounded umbo at lengths
			H = 81-305		422	85-90Mm; knoblike
Pediveliger	16-22 days		D = 62-200			umbo at lengths 91-150
						µm; skewed umbo at
						lengths greater than
	16-22 days					150 µm
			L = 210-275		18	alternately creeping and
			H = 240-305		15	swimming vigorously
Eye-spotted pediveliger	18-22 days		D = 171-220		6	
		L 217				larvae nearing metamor-
		H 242				phosis; eye-spot diameter,
Spat	20 days					range 8-15
		L 274				larvae attached on
		H 328				cultches



Table 3. Major features of larval development in *Placuna placenta* cultured at 27°C and 28-29 ppt salinity (Young 1980)

Stage	Age	Size range (Mm)	Shape/distinguishing features
Fertilized egg	0	Dia. 45 µm	Golden yellow, spherical
Straight-hinge	20-30 h	L:50-105 H:43-98 D:25-52 HL:4-55	Smallest veliger 50x43 µm; hinge line commonly 50-55 µm, slightly curved, not increasing in length with growth. Ends of nearly equal length. Shell inequivalve.
Umbo veliger	2-8 days	L: 100-200 H:80-200 D:50-75	Shells inequivalve. Right valve flat with undeveloped umbo. Left valve rounded. At lengths beyond 150 µm umbo of left valve projects well above the shoulders as a prominent knob. Shells nearly transparent; digestive organs situated almost beneath umbo, No byssus notch. Anterior end longer, more pointed. Ventral margin bluntly pointed.
Pediveliger	8-10 days	L: 180-220 H:180-220	Foot functional at L=170 µm. Eyespots at L=150, commonly obscured by opaque mass of digestive gland. Metamorphosis at L:220-230.
Spat	10-11 days	Typically L:230 H:220	Foot long, well developed. Velum absent. Dissoconch delineated by narrow dark band. Shells nearly transparent.

3-ton tanks with 15 larvae/ml. The tanks were maintained on a 24-hr basis after which about 30-50% of the bottom water was siphoned and replaced by rearing water pretreated with sodium hypochlorite and filtered through a P-5 polypropylene cartridge of the dirt/rust type capable of removing particles of 5  $\mu\text{m}$  and further disinfected through a UV sterilizer. Larvae were fed with *Isochrysis galbana* during the first week and then a combination thereafter of *Isochrysis* with either *Tetraselmis chuii* or *Chaetoceros calcitrans* at  $5.0 \times 10^4$  cells/ml. Total water renewal was done every fifth day. The high density stocking method yielded an average of 2.36 million ready-to-settle (5.3% survival) mussel larvae in 20 days.

Mass mortalities caused by bacterial population reaching lethal levels in the larval tanks were encountered in the trials. Contaminants were traced to bacterized algal feed from 10 l plastic carboys used in mass production of feeds. Poor growth and survival were particularly evident in larvae fed with algae at  $7.5 \times 10^4$  cells/ml. The production of pseudofeces of overfed larvae promoted the proliferation of bacteria in the cultures, and despite total water renewals, cumulative blooms from residual bacterial populations still prevailed. *Vibrio* sp., a well known pathogenic bacteria, especially virulent to bivalve larvae, was present. Of the anti-bacterials tested, only the mixture of penicillin and streptomycin was found effective in promoting growth and survival of larvae. Sulfadiazine and sulfamerazine were ineffective in depressing bacterial growth.

## DEPURATION

Oysters and mussels, which have high bacterial concentrations can be purified by placing them in unpolluted water and allowing such water to be filtered by the bivalves. The bacteria, usually concentrated in the guts are excreted as feces and those in the gill region as pseudofeces. This purification process ensures that bivalves are safe for consumption.

In 1983, a prototype low-cost depuration unit suitable for local conditions was set up in the Tigbauan Main Station (Fig. 2). Experimental tank No. 1 is made of 20 mm marine plywood coated inside with fiberglass resin. Oysters are placed individually in plastic trays at 20 pieces/tray, and loaded on the rectangular depuration tank, (No. 4). Water, prefiltered with a P-5 polypropylene cartridge of the dirt/rust type enters the tank at 7l/min and trickles through a perforated PVC pipe placed at the proximal end of the tank (No. 2).

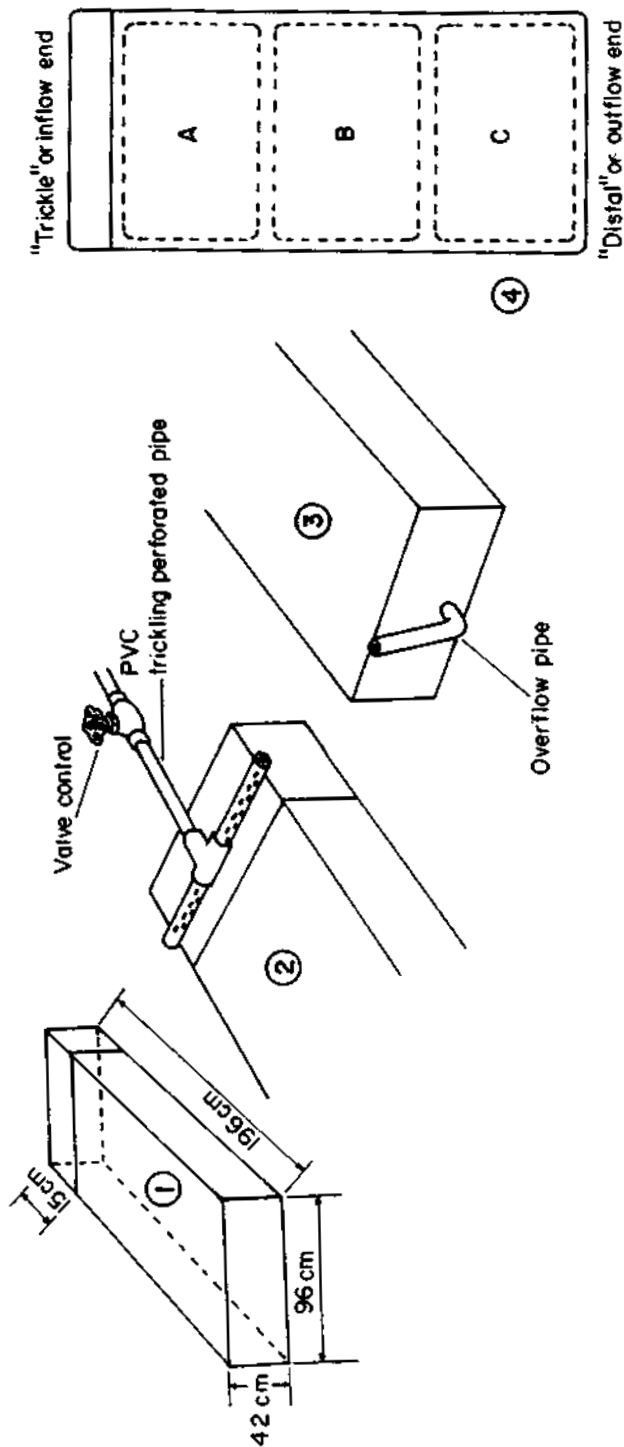


Fig. 2. Experimental depuration unit (Gacutan et al 1986)

Water is disinfected further by passing it through a UV sterilizer. At the distal end, water is drained through a 2.5 cm overflow pipe located at a height level with the tank floor (No. 13). Freshly harvested oysters were depurated by using microbiologically clean sea water sterilized by treatments with chlorine, UV, ozone, polyvinylpyrrolidone-iodide-iodine and sand-filtered in a flow-through system. In terms of bacterial disinfection efficiency, ultra violet-treated water was found to be 99% efficient after 48 h (Gacutan et al 1986). UV radiation may be most suitable for the region as it has no residual effect, is easy to use, and is comparatively inexpensive. Figure 3 shows the changes in the fecal coliform load in oysters during depuration.

Bivalves are known to accumulate heavy metals in their body tissues. In 1981, a sample of the natural population of green mussels in Batan Bay, Aklan was found to contain mercury. A study was therefore conducted to determine mercury uptake by the mussel, its depuration capability, and the possible pathway of mercury bioaccumulation. Results show that the green mussel accumulates mercury rapidly from its surroundings but is very slow in self-cleansing (Fig. 4). This is significant since mussels can be utilized as indicators for presence of trace metals and organochlorines in tropical waters. In July-August 1983, a red-tide occurred in Western Samar and Leyte, covering approximately 300 km of coastlines and lagoons. The causative dinoflagellate was *Pyrodinium bahamense* var. *compressa*, the same organism that caused several red-tide outbreaks in Papua New Guinea, Sabah, Brunei, and Palau.

Average toxicity of red-tide contaminated green mussels was 1165 MU/100 g (range 945-1,310 MU/100 g) (Gacutan et al 1984). On the basis of the equivalence of 1 MU to 0.18 µg of saxitoxin, the toxicity was 213 µg/100 g almost triple the threshold set by the US Food and Drug Administration for closure of shellfish beds (i.e., 80 µg/100 g). When undiluted extracts were injected into mice, killing times averaged 2.5-3.5 minutes. The shortest killing time was recorded at 1.5 min (Gacutan et al 1986).

Preliminary results pointed to the possibility of using ozone and PVP-iodide-iodine to inactivate PSP toxins in green mussels (Gacutan et al 1984).

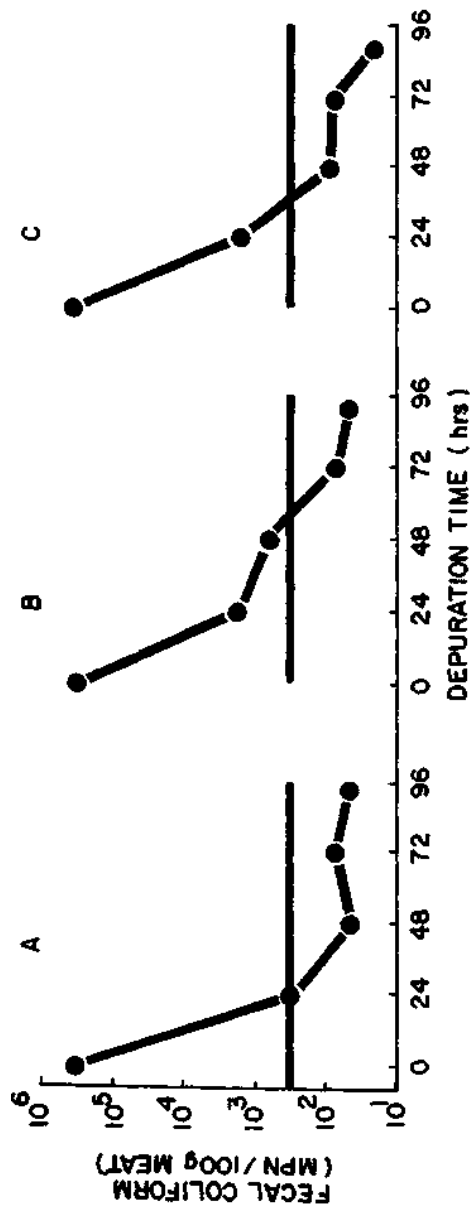


Fig. 3. Changes in the fecal coliform (FC) load (MPN/100 g meat) in the slipper oyster *Crassostrea iredalei* from three areas of a 4 × 8 m wooden tank during depuration of 96 hours (Gacutan et al 1986)

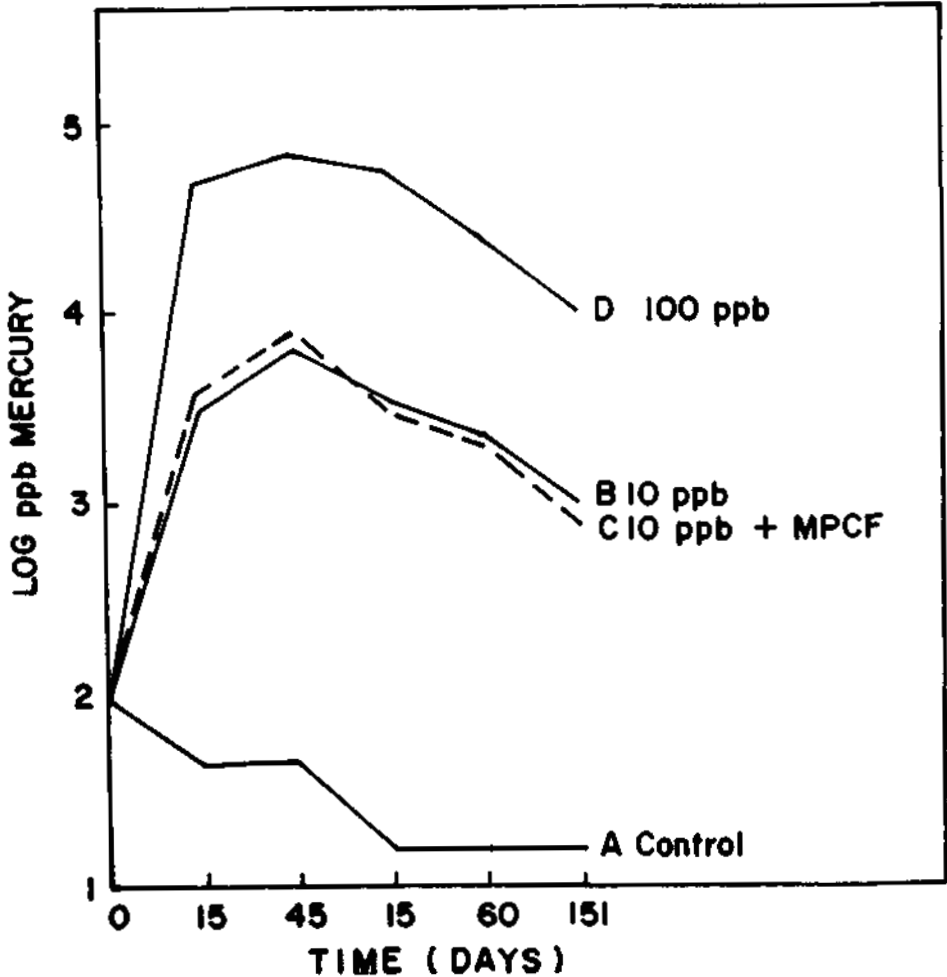


Fig. 4. Accumulation and elimination of mercury by green mussels (Rosell 1985)

### TRANSPORT AND HANDLING

In 1976, the Department started conducting experiments on Postharvest handling. Results showed that large mussels are more hardy than small ones and that keeping them wet with sea water prolongs their survival after harvest (Yap and Orano 1980). The bacteriological flora of the slipper oyster was also examined and the results shown in Table 4 (Llobrera et al 1986). A related study showed that while other forms of storage such as freezing and chilling arrest meat spoilage for several days, the most practical storage condition is by placing the meat under a blanket of ice. Oyster meat under a blanket of ice retains its wholesome quality for 14 days, thus extending its marketing possibilities.

Table 4. Percentage distribution of the microbial flora of oysters stored at different temperature (Llobrera et al 1986)

Storage temperature	Day		Enterobacteriaceae									
			Pseudomonas	Vibrio	Aeromonas	Flavobacterium	Acinetobacter/Moraxella	Coryneforms	Micrococcus	Bacillus	Streptococcus	Staphylococcus
A Room temperature 24°C	0	10.3	6.9	13.8	6.9	13.8	10.3		6.9	6.9	3.4	13.8
	2	30.4	19.6	13.0	6.5	8.7	4.3	10.8	6.5			
	0	12.5	2.5	22.5		12.5	7.5	37.5	2.5	2.5		
	4	20.0		20.0	10.0	10.0						40.0
Under ice blanket 34°C	8	66.6				33.3		28.6				
	12	71.4						10.5	5.3			
	14	68.4		10.5		5.3						
	0	7.7	18.0	38.5		7.7		23.1		5.0		
C Chilled 4°C	4	12.5		12.5		6.3		31.2				37.5
	8	28.6	14.3	21.4		14.3		7.1		7.1		7.1
	12		14.3		14.3			28.6	14.3		28.6	
	22								100.0			

D Frozen -25°C	0	36.8	7.9	13.2	7.9	5.3	26.3	2.6	
	4	23.5		17.6	5.9	5.9	29.4		17.6
	8	14.3		21.4	14.3	28.6	14.3		
	12	8.3		33.3		8.3	8.3	25.0	16.7
	16	36.3			9.1	18.2	18.2		18.2
	20	20.0				6.6	46.7	26.7	
	24	16.6					16.6	66.7	
	28	25.0					16.6	16.6	
	32	18.2					18.2	27.3	
	36	6.7		6.7			13.3	46.7	13.3
	40	25.0					43.8	18.8	6.2
	44	66.7					6.7	13.3	
	48	26.3					52.6	5.3	
	52	21.0		5.3		21.8	26.3	10.5	
	56	31.7					26.3	10.5	
	64	30.8		15.4	20.5	5.1	10.2	5.1	5.1



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